A multiaperture electron filter for volume-type H^- ion source

S. Hahto,[a] K. Leung, A. Persaud, and J. Reijonen
Lawrence Berkeley National Laboratory, 1 Cyclotron Road, Berkeley 94720, California

(Presented on 6 September 2001)

Negative light ion beams have been used widely in many applications over the past decades. One of the most popular methods of producing H^- and D^- beams is the so-called volume production, in which a plasma is contained in a multicusp magnetic field. The beam is extracted using an electric field applied in the extraction gap. Accompanying the negative ions is up to 100 times greater number of electrons, which have to be removed from the beam. This is usually done by placing a transverse magnetic field in the extraction region. With this method the electrons can be quite effectively removed from the beam. The problem is that we dump a high intensity, high energy electron beam in the extraction electrode and dissipate a lot of power in the process. The negative ion beam is also deflected in this strong magnetic field which has to be corrected either by tilting the source compared to the extraction or by adding an opposite transverse magnetic field. In the latter method the beam is laterally displaced from the original axis. In the Plasma and Ion Source Technology Group at the Lawrence Berkeley National Laboratory, we are developing a multi-aperture extraction in which the electrons are removed from the beam before they are accelerated to high energy with the use of a honeycomb-structured electron filter and a weak magnetic field. This way the power dissipated by the electrons and the ion beam deflection are minimized. The initial results of these experiments will be described in this presentation. [DOI: 10.1063/1.1431409]

I. ELECTRON FILTERING IN A VOLUME-TYPE H^- SOURCE

In volume-type H^- sources the electron filtering is usually performed in the extraction region after the beam has been accelerated to energy of a few keV's. The electrons can be turned away with a strong magnetic field placed just after the extraction aperture and correcting the beam deflection by tilting the ion source, as is done in the spallation neutron source (SNS) H^- ion source at the Lawrence Berkeley National Laboratory (LBNL).[1] In the SNS H^- source, the beam deflection can be up to 3°. The other method is to correct the ion beam trajectories with a reverse magnetic field, as is done in H^- sources at TRIUMF, Canada, and Jyväskylä, Finland.[2] In this method the beam is laterally displaced from its original axis. Figures 1(a) and 1(b) show the principle of these two methods.

II. NEW MULTIAPERTURE ELECTRON FILTER AT LBNL

The new electron filter developed at LBNL's Plasma and Ion Source Technology Group is a multi-aperture honeycomb structure, which uses a magnetic field of approximately 50 G to effectively move electrons from the extracted H^- beam before they are accelerated to high energy. Because of this, the dissipated power by the electrons is small and the ion beam deflection can also be reduced. Figure 2 shows a schematic picture of the grid extraction system. The grid consists of three primary components. The first is a thin plasma grid. It is positively biased up to 100 V relative to the ion source. The second part is the high aspect ratio electron filter grid. It has the same hole pattern and diameter as the plasma grid and it is biased from 100 to 200 V positive voltage relative to the plasma grid. The plasma meniscus is formed between the grids and a beam is extracted. Permanent magnets are used to create a transverse magnetic field in the electron filter grid area. High aspect ratio of the grid channel means that the 50 G magnetic field is sufficient to turn the electrons from the beam. When the electrons and some of the ions are hitting the channel wall, some secondary electrons are emitted and can be accelerated with the beam if they diffuse out of the grid channel, which in turn increases the electron content of the beam. To minimize this effect, a fine tungsten mesh is installed after the electron grid. It is biased to a few tens of volts negative voltage compared to the electron grid to trap the secondary electrons in the channel.

III. SIMULATIONS OF THE ELECTRON FILTER

Ion beam simulations were conducted to achieve the optimal magnetic field strength and to study electron filter design geometry. KOBRA3-INP[3] code was used to determine the optimal magnetic field strength and IGUN[4] beam simulation code was used to compare different extraction geometries. In Fig. 3, a KOBRA simulation for 1 mm aperture size is shown. In Fig. 3, the bias voltage of the electron grid relative to the plasma grid was 250 V. The magnetic field used in the simulations was obtained by setting up the SmCo magnets and measuring their field at the simulation geometry. The measured profile of the *z* component of the magnetic field is shown in the lower part of Fig. 3. The average magnetic field

[a]Electric mail: skhahto@lbl.gov

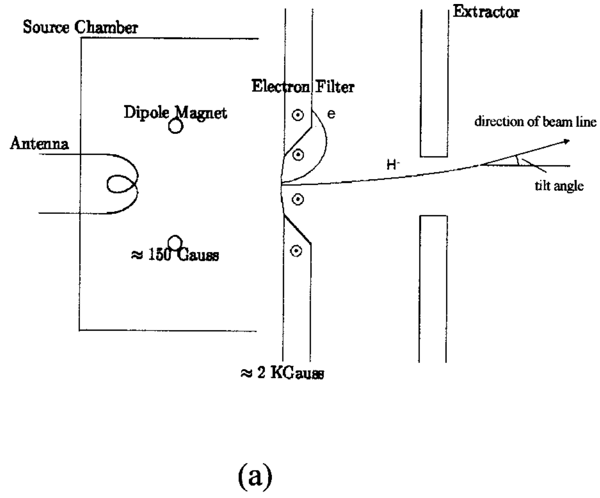

FIG. 1. Schematic picture of (a) SNS H^- ion source and (b) TRIUMF H^- ion source electron filtering.

along the center axis of the grid geometry was about 50 G, which was sufficient to turn the electrons away from the beam effectively. The beam was deflected in this simulation by approximately 0.5°. By increasing the aspect ratio of the electron grid, even weaker magnetic fields are sufficient to filter the electrons out.

Ion beam optics were simulated using the IGUN ion beam simulation code. The formation and transport of the beam in the grid system were simulated and the optimal gap and voltage for the grids were evaluated. In Fig. 4, an IGUN simulation of one a 1-mm-diam extraction aperture is shown. The electron grid is biased 250 V positive compared to the plasma grid.

IGUN simulations show that it should be possible to extract and transport effectively H^- beam with the multiaperture grid system.

IV. EXPERIMENTAL SETUP

For the initial tests a 61 hole multiaperture electron filter with 0.5 mm aperture size was constructed. The electron grid had aspect ratio of 6. It was installed in a 10-cm-diam rf multicusp source with an internal magnetic filter. Up to 100 times more electrons than H^- ions are extracted from this type of source. Ion and electron currents were measured with a two stage Faraday cup in which the electrons and ions are separated with a transverse magnetic field.

V. RESULTS

The initial tests were carried out with the experimental setup described above. Hydrogen plasma was produced with

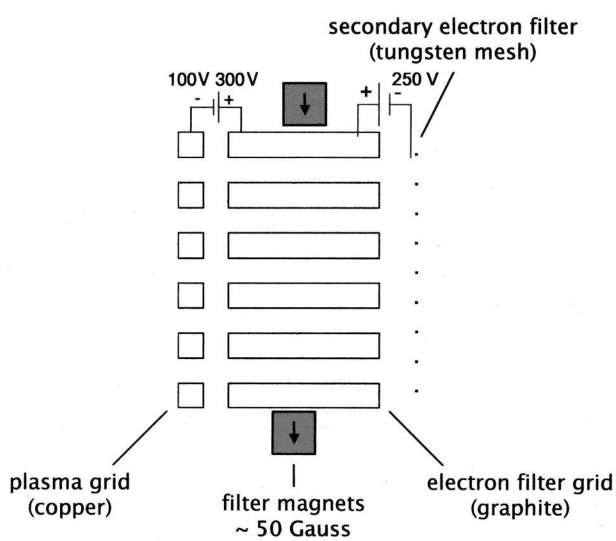

FIG. 2. Schematic picture of the new multiaperture H^- extraction developed at LBNL.

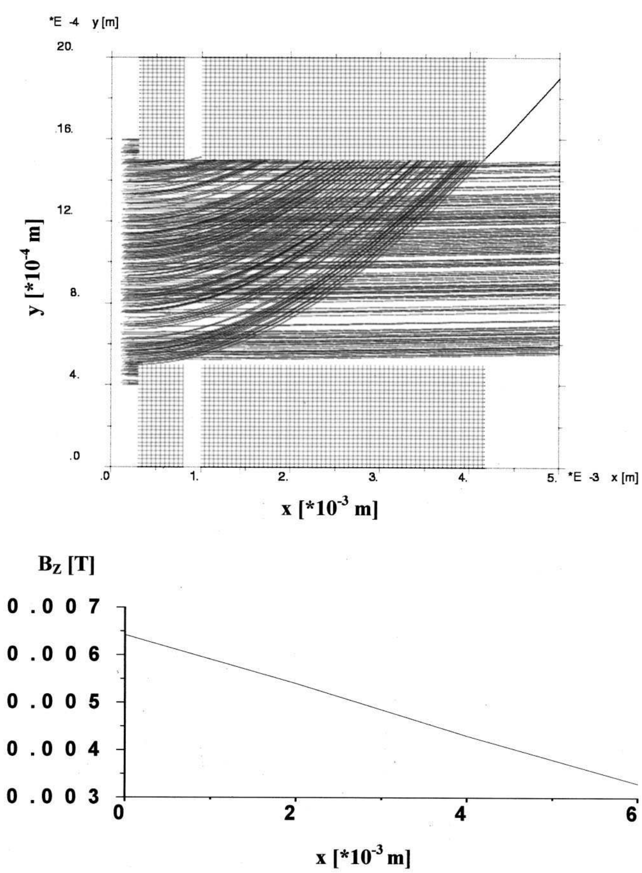

FIG. 3. KOBRA simulation of 1 mm grid aperture with 50 G average magnetic field.

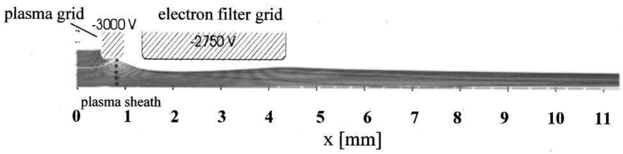

FIG. 4. IGUN simulation for 1-mm-diam aperture.

1 kW rf power and with 7 mTorr plasma chamber pressure. In Fig. 5 measured H^- and electron currents and the ratio of the two are plotted as a function of electron grid voltage.

With low electron grid voltages, the ratio I_e/I_{H^-} is reasonably high. This is caused by the low extracting electric field which causes the plasma meniscus to blow out. Most of the beam is lost in the electron grid channel. When electron grid voltage and thus extracting electric field are increased the beam intensity increases and also it is transported more efficiently through the grid. The ratio I_e/I_{H^-} reaches its minimum value of 0.4 at the electron grid voltage of 90 V. The secondary electron grid did not have a noticeable effect to the I_e/I_{H^-} ratio. This may be due to the fact that most of the secondary electrons in the electron grid channel are created in the first half of the grid and the magnetic field in that area is sufficient to turn them back to the channel wall. The measurements were carried out without cesium injection to the source.

VI. DISCUSSION

A new kind of electron filter for a volume-type H^- source has been developed at LBNL. The goal was to show that most of the electrons extracted from the source can be filtered out with a multiaperture honeycomb-structured extraction combined with a weak magnetic field. The ratio of the electron and ion currents was reduced to a minimum value of 0.4. Further experiments with cesiated ion source operations are planned and the goal is to reduce the I_e/I_{H^-} ratio further.

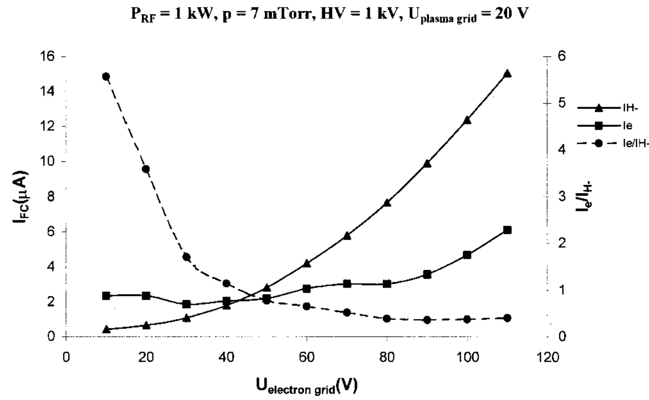

FIG. 5. Measured H^- and electron currents and the ratio of the two.

ACKNOWLEDGMENT

This work is supported by the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

[1] M. A. Leitner, D. C. Wutte, and K. N. Leung, Rev. Sci. Instrum. **69**, 965 (1998).
[2] T. Kuo *et al.*, *Proceedings of the 14th International Conference on Cyclotrons and Applications* (World Scientific, Singapore, 1996), p. 420.
[3] P. Spädtke, KOBRA3-INP user manual, version 3.39 (2000).
[4] R. Becker and W. B. Hermannsfeldt, Rev. Sci. Instrum. **63**, 2756 (1992).